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DIVISION OF ENGINEERING AND WEAPONS

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**UNMANNED TESTING OF A MODIFIED
US DIVERS OXYMIX SEMI-CLOSED UBA
WITH VARIABLE EXHAUST VOLUME RATIOS**

**Marshall L. Nuckols*
W. A. Gavin, Jr.
W. Scott Finlayson**

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***Professor**

Naval Architecture and Ocean Engineering Department

U.S. Naval Academy

Annapolis, Maryland

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UNMANNED TESTING OF A MODIFIED US DIVERS OXYMIX SEMI-CLOSED UBA WITH VARIABLE EXHAUST VOLUME RATIOS

ABSTRACT

An analytical model has recently been developed for predicting the circuit oxygen levels in semi-closed underwater breathing apparatus at various mission depths and diver activity levels (Nuckols, Clarke, Marr, 1999). Unmanned testing in June 2000 with a commercially available US Divers Aqualung OxyMix rebreather (NEDU Test Plan Number 00-06 dated May 2000) showed good agreement with this analytical model over a wide range of diver depths, orientations and activity levels (Nuckols, Gavin, Finlayson, 2000). However, the model indicated that an enhanced performance capability could possibly be achieved with the OxyMix by modifying the size of its exhaust bellows and changing the oxygen content of the supply gas. Following the tests in June, an optimization approach was applied to the analytical model to define desired design parameters for the OxyMix rebreather to maximize its excursion depth capability. Optimized exhaust volume ratios (EVR), the ratio of the small inner bellows volume relative to the main breathing bellows, and supply gas oxygen concentrations were identified to maximize safe operations for the OxyMix design. US Divers agreed to fabricate two modified exhaust bellows of varying volumes for testing to verify the predicted performances of the modified OxyMix rebreather. During the week of 18 December 2000, unmanned testing with these modified OxyMix rebreathers at the Experimental Dive Facility at NEDU verified predicted performances. Specific findings in these tests included

- a) a modified OxyMix rebreather using an exhaust volume ratio of approximately 6.25% and a supply gas mixture containing 37% oxygen was shown to give an excursion capability to 130 FSW while maintaining circuit PO_2 levels below 1.32 Ata (excursions to 150 FSW were shown to be possible with maximum PO_2 levels below 1.6 Ata)
- b) similar to the results seen in the June tests, circuit PO_2 levels were shown to be unaffected by diver activity rates between RMV's of 22.5 LPM and 62.5 LPM
- c) the addition of a diluent injection system on the modified OxyMix design provided minimum circuit oxygen levels of 0.42 Ata at 20 FSW and 0.25 Ata at 0 FSW while still maintaining circuit PO_2 levels below 1.32 Ata for excursions up to 130 FSW

INTRODUCTION

During June 2000 the U.S. Divers Oxymix 3C, shown in Figure 1, was tested in the Experimental Dive Facility (EDF) at NEDU as outlined by Test Plan 00-06. The Oxymix apparatus functions as a ventilatory-coupled rebreather when in semi-closed mode, but has the capability of being manually switched to a closed, pure oxygen mode by the diver when in shallow depths. The Oxymix system is made up of two units, chest and back mounted. The chest unit contains the breathing bellows and carbon dioxide scrubber. The back unit contains three 2-liter cylinders, one containing pure oxygen used during closed circuit mode and the other two containing a nitrox mixture for injection when in semi-closed circuit mode.

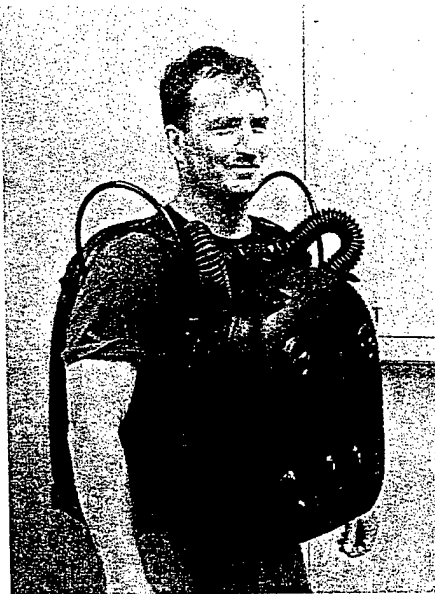


Figure 1: U.S. Divers OxyMix 3C. The chest pack contains the breathing bellows and the carbon dioxide scrubber. The backpack encloses the gas supply bottles.

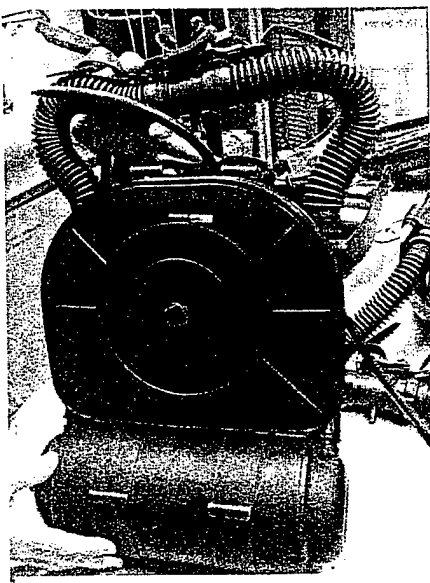


Figure 2: OxyMix 3C with front cover removed showing the main breathing bellows and the carbon dioxide scrubber.

The breathing bellows assembly, shown in Figure 2, contains two bellows, the main breathing bellows which houses a smaller inner bellows. The small inner bellows, shown in Figure 3, is fixed in position on one end by a fixed inner plate and on the other end by the upper mobile plate attached to the main breathing bellows. Both bellows are concentric and operate together as the diver inhales and exhales, making their action proportional to the breathing rate of the diver. Fresh makeup gas is added to the circuit through a mechanical demand valve as the main breathing bellows collapses during diver inhalation, forcing the mobile plate to press on the valve actuator, as shown in Figure 4.

All testing in the June test series was unmanned. Prior to these tests, an exhaust volume ratio (EVR), the ratio of the small inner bellows volume relative to the main breathing bellows, of approximately 10 to 11% was measured for the standard off-the-shelf OxyMix rig. Three test depths (20, 60, and 80 FSW) and three RMV levels (22.5, 40, and 62.5 lpm) were investigated during these model validation tests. Corresponding oxygen consumption rates as prescribed by NEDU Test Manual 01-94 were simulated during each test combination of depth and RMV. PO_2 versus time were monitored in the breathing circuits of two OxyMix rigs at each depth/RMV combination while simulating diver oxygen consumption until stabilized PO_2 levels were observed. A nitrox mixture containing 50% oxygen, as prescribed by U.S. Divers, was used as the makeup gas at all test conditions. Both rigs were tested at each depth/RMV combination twice to confirm the repeatability of test data. Different diver orientations (prone, supine and vertical) were tested to determine whether diver position would have any impact on these circuit oxygen levels. Figure 5 summarizes the results of this earlier testing with an off-the-shelf OxyMix rebreather.

These tests verified the predictions made by the analytical model. In addition, this testing verified that circuit oxygen levels were repeatable and remained constant over the range of diver activity levels tested. This constant and repeatable circuit behavior was considered to be extremely desirable for a mission in which a wide range in diver activity levels could occur. In addition the analytical model, supported by results from these tests, indicated that

the OxyMix mission capability could be extended significantly by reducing the exhaust volume ratio (EVR) while simultaneously reducing the supply gas oxygen concentrations as shown in Figures 6 and 7.



Figure 3: View of exhaust bellows housed inside the main breathing bellows.

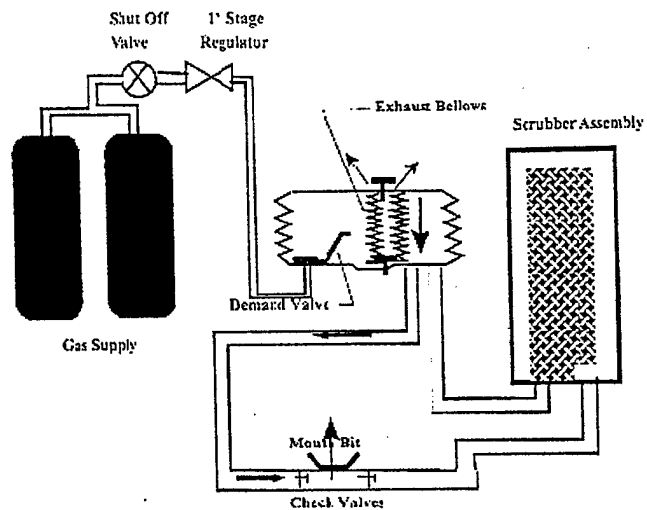


Figure 4: Simplified circuit diagram for the OxyMix 3C

Model Validation Testing VVE; 50/50 nitrox

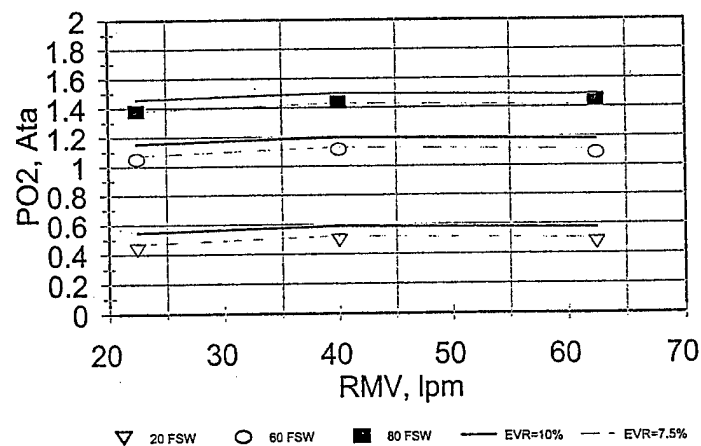


Figure 5: Performance of off-the-shelf OxyMix rebreather using a 50% oxygen supply gas.

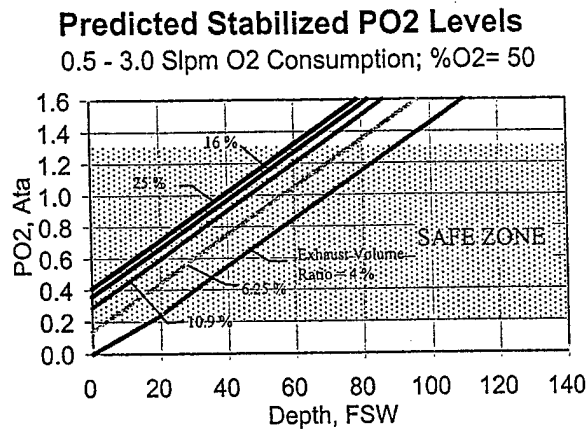


Figure 6: Model predictions for an OxyMix rebreather using a 50% oxygen supply gas.

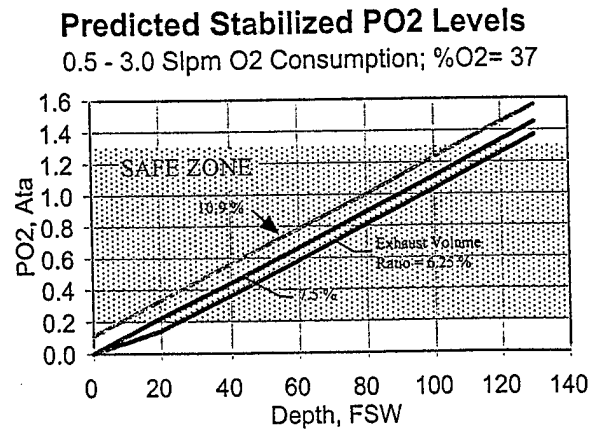


Figure 7: Model predictions for a modified OxyMix rebreather using a 37% oxygen supply gas.

PROCEDURES FOR MODIFIED OXYMIX TESTING

During the week of 18 December 2000, two (2) U.S. Divers OxyMix rigs, one off-the-shelf and one having varying modified exhaust bellows sizes, were sequentially tested in semi-closed circuit mode as outlined in NEDU test plan number 00-21. The modified rigs containing reduced EVRs of 6.25% - 7.5% were predicted to give the OxyMix a depth capability of up to 130 FSW, while maintaining maximum circuit PO₂ levels below approximately 1.3 Ata, when using a supply gas containing 37% oxygen. All testing was unmanned using one of the Experimental Diving Facility (EDF) chambers, a breathing simulator, and the EDF oxygen consumption simulator. UBA circuit PO₂ versus time were continuously recorded at depths of 130, 75 and 20 FSW, and at respiratory minute volumes (RMVs) of 22.5 LPM and 62.5 LPM while using a 37% oxygen gas supply. Corresponding oxygen consumption rates were simulated during each test combination of depth and RMV as shown in Table 1. Additionally, circuit pressures were continually monitored in the mouth bit to allow determination of the circuit breathing resistance at each depth/RMV combination; i.e., work-of-breathing (WOB).

During all testing the rigs were submerged in a water bath at a temperature of approximately 70°F within the EDF chamber. Prior to commencement of testing for each rig, the following baseline calibrations were completed.

- Calibrated all pressure transducers in accordance with their pressure ranges, ensuring as a minimum a zero reference point, mid-range and full-scale point.
- Calibrated the Rosemount 755 oxygen analyzer over the anticipated ranges of the UBA performance characteristics.
- Verified that the UBA has been configured according to manufacturer's operational specifications as per OxyMix Users Manual.
- Verified that tank temperature is within specified parameters.

- e. Ensured completion of EDF chamber operating procedures, test equipment connections and all calibrations were complete.
- f. Recorded UBA test specifics in the EDF Diving Supervisors log and installed on test stand in the upright position.
- g. Lowered UBA into ark and verified UBA and test support equipment was gas tight (leak check).
- h. Performed final systems checks to ensure that all instrumentation was functioning.

Testing began by pressurizing the water bath to a simulated depth of 130 FSW at a travel rate of 60 FSW/min. Upon reaching 130 FSW, a simulated respiratory rate of 22.5 LPM was initiated and PO_2 versus time was recorded until stable levels were reached. Following stability the RMV was increased to 62.5 LPM and PO_2 versus time was recorded until stability was met.

Following testing at 130 FSW, the chamber was vented to a simulated depth of 75 FSW at a travel rate of 30 FSW/min (Note: The main breathing bellows was observed to over inflate when using a planned travel rate of 60 FSW/min). PO_2 versus time was recorded continually during this ascent period. Upon reaching 75 FSW testing was conducted in the reverse order of that used during previous testing at 130 FSW; i.e., PO_2 versus time recorded at the highest RMV initially followed by testing at the lower RMV.

After completing tests at 75 FSW, the chamber was again vented to a simulated depth of 20 FSW at a travel rate of 30 FSW/min, continually recording circuit PO_2 versus time during the ascent. Upon reaching 20 FSW testing was continued with the order of RMV testing set at 62.5 LPM followed by 22.5 LPM.

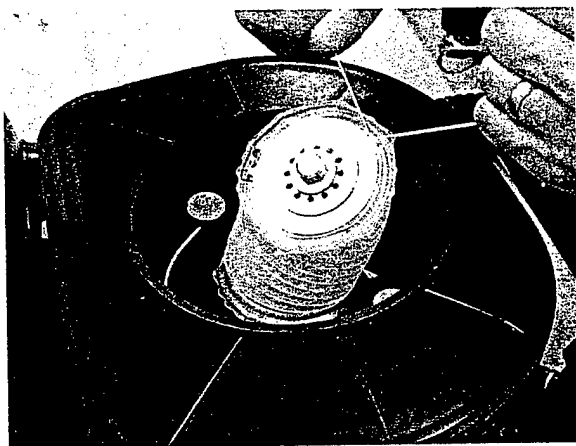


Figure 8: Assembling a smaller inner exhaust bellows to give a reduced EVR.

Following testing of the first standard OxyMix rig at all depth/RMV conditions, testing was repeated with the OxyMix, modified as shown in Figure 8, using the same procedure as described above while monitoring PO_2 versus time until stability in circuit PO_2 was observed. Note: During some depth/RMV combinations the oxygen consumption simulator was not able to function as desired due to excessive gas flow rates through the mass controllers. Under these conditions, the oxygen consumption rates or depths were altered as indicated in Table 2.

Table 1. RMV/ O_2 consumption schematic.

<u>RMV RATE</u>	<u>O_2 CONSUMPTION RATE</u>
22.5 LPM	0.9 SLPM
62.5 LPM	2.5 SLPM

RESULTS

Table 2 summarizes the stabilized circuit oxygen levels for the standard and modified OxyMix rigs over the range of depth/RMV combinations tested. These results are shown graphically in Figure 9 along with model predictions made for EVRs of 10.9% (standard bellows) and 6.25% (small bellows).

Table 2: Stabilized circuit oxygen levels.

Standard bellows – Nominal diameter of exhaust bellows = 3.0 inches (EVR = 10-10.9%)				
Depth, FSW	Oxygen consumption rate, slpm	RMV, LPM	Stabilized circuit oxygen level, Ata	WOB J/L
130	0.9	22.5	1.48	1.1
	2.5	62.5	1.46	4.09
75	2.5	62.5	0.86	3.17
	0.9	22.5	0.84	0.92
20	0.9	22.5	0.17	0.72
50	2.5	62.5	0.57	2.92
20	1.6	40.0	0.25	1.36
20	0.9	22.5	0.18	0.72
Modified rig #1-Small bellows – Nominal diameter of exhaust bellows = 2.4 inches (EVR is approx 6-6.25%)				
130	0.9	22.5	1.33	1.02
	2.5	62.5	1.32	4.03
75	2.5	62.5	0.73	3.04
	0.9	22.5	0.69	0.83
20	0.9	22.5	0.14	0.63
	0.9	22.5	0.14	0.63
Modified rig #2 – Medium bellows– Nominal diameter of exhaust bellows = 2.6 inches (EVR is approx 7.5%)				
130	0.9	22.5	1.44	1.05
	2.5	62.5	1.42	4.15
75	2.5	62.5	0.81	2.87
	0.9	22.5	0.79	0.84
20	0.9	22.5	0.17	0.63
	1.6	40.0	0.17	0.63
Modified rig #1- Small bellows with shallow water injection system (EVR approx 6-6.25%)				
75	0.9	22.5	0.7	0.88
20	0.9	22.5	0.54	0.59
30	0.9	22.5	0.64	0.72
40	0.9	22.5	0.74	0.75
50	0.9	22.5	0.33	0.80
20	2.5	62.5	0.42	1.73
30	2.5	62.5	0.50	1.95
40	2.5	62.5	0.59	2.15

Observe in Figure 9 that circuit oxygen levels of approximately 1.32 Ata were recorded at 130 FSW when using the smallest exhaust bellows with 37% oxygen supply gas. This same circuit oxygen level would be expected at less than 70 FSW with the standard bellows when using 50% oxygen (see Figure 6), and 110 FSW with the standard bellows when using 37%

oxygen (see Figure 7). Circuit oxygen levels of 1.6 Ata at 150 FSW can be projected for the small bellows with a 37% oxygen supply setup. A negative impact of this enhanced depth capability when using the smaller bellows and lower oxygen percentages is low circuit oxygen levels when near the surface. Observe in Figure 9 that circuit oxygen levels of 0.14 Ata were recorded at 20 FSW with the smallest exhaust bellows. If a diver were to switch to the closed circuit, pure oxygen mode upon reaching 20 FSW, he could resolve these dangerously low oxygen levels manually. However, such a resolution would be difficult if the diver is forced to make an emergency ascent to the surface without being able to stop at 20 FSW to make the switch over. Another method to resolve these low circuit oxygen levels is to use a supplemental gas injection system that increases oxygen addition to the circuit only at shallow depths. Such a shallow water injection system has been used in the past on the U.S. Divers DC-55 rebreather. In effect, this system operates similar to sonic orifice injection systems while near the surface and then converts to the ventilatory-coupled injection beyond approximately 45 FSW.

As a supplement to NEDU test plan 00-21, a modified OxyMix, using the small exhaust bellows and a shallow water injection system as shown in Figure 10, was tested as described above. The supplemental gas injection system operates with a simple spring-loaded valve that regulates supply gas flow at shallow depths. This valve remains open between depths of 0-15 meters (0-45 FSW), and closes at depths beyond 45 FSW. At depths beyond 45 FSW the shallow water injection system is closed off and the rig behaves the same as previously shown in Figure 9 without supplemental injection. U.S. Divers personnel characterized the shallow water injection system used in this testing as supplying 17 liters per minute of supplemental gas injection (using the same 37% oxygen supply gas) at surface pressures. It is assumed that this injection rate is gradually reduced between the surface and the cut-off depth of approximately 45 FSW.

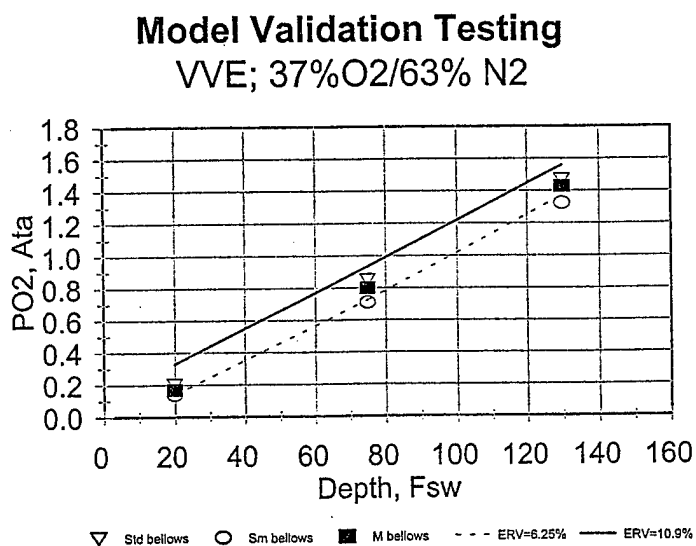
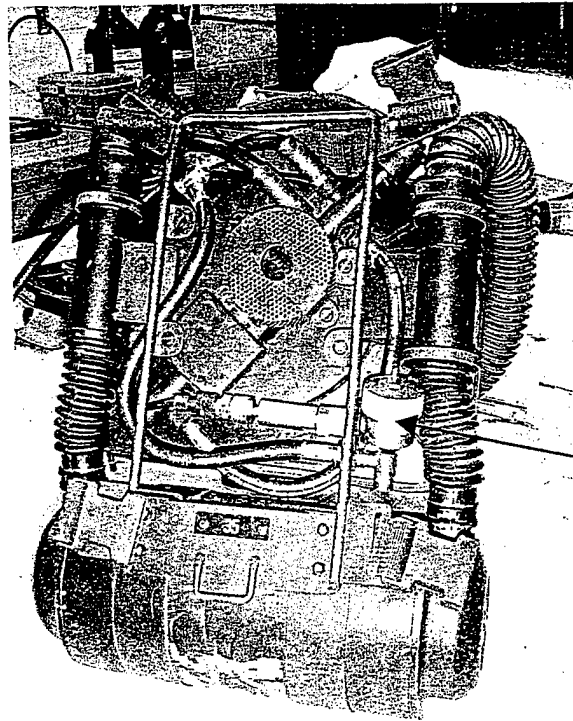


Figure 9: Comparison of stabilized circuit oxygen partial pressures when using different EVRs.



Spring-loaded valve that activates supplemental gas injection at shallow depths.

Figure 10: Modified OxyMix with a shallow water, supplemental gas injection system.

Figure 11 shows the beneficial effect of this shallow water injection system in elevating circuit oxygen levels when near the surface. Without supplemental injection, circuit oxygen levels when using the smallest exhaust bellows were observed to drop to 0.14 Ata at 20 FSW. When the supplemental gas injection system was added to the OxyMix rebreather having the same small exhaust bellows, circuit oxygen levels never dropped below 0.4 Ata at 20 FSW at an RMV of 62.5 LPM or below 0.5 Ata at an RMV of 22.5 LPM. Even at the highest diver activity level of 62.5 LPM, the circuit oxygen levels are projected to remain above 0.2 Ata at the surface.

Effect of Shallow Water Injection

37% O₂; 2.4-inch inner bellows

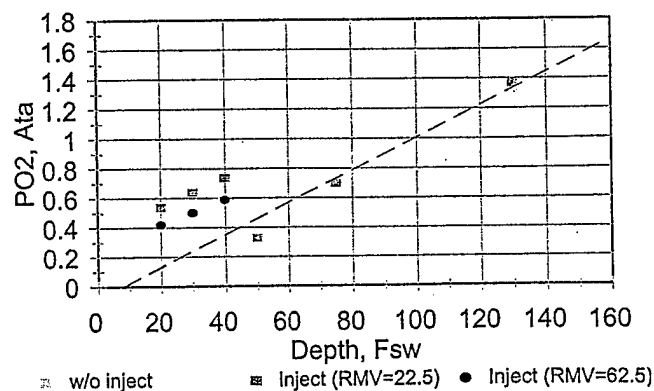


Figure 11: Effect on circuit oxygen levels recorded in a modified OxyMix rebreather with the addition of a shallow water injection system.

CONCLUSIONS

Testing with modified OxyMix rebreathers have verified the benefits of using reduced exhaust volume ratios (EVRs) and supply gas oxygen concentrations to maximize mission depth capability. A modified OxyMix rebreather using an exhaust volume ratio of approximately 6.25% and a supply gas mixture containing 37% oxygen was shown to give an excursion capability to 130 FSW while maintaining circuit PO_2 levels below 1.32 Ata (excursions to 150 FSW were shown to be possible with maximum PO_2 levels below 1.6 Ata). These circuit oxygen levels were shown to be unaffected by diver activity rates between RMV's of 22.5 LPM and 62.5 LPM.

The addition of a shallow water injection system on the modified OxyMix design provided minimum circuit oxygen levels of 0.42 Ata at 20 FSW and 0.25 Ata (projected) at 0 FSW while still maintaining circuit PO_2 levels below 1.32 Ata for excursions up to 130 FSW.

REFERENCES

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2. "Assessment of Oxygen Levels In Alternative Designs Of Semi-Closed Underwater Breathing Apparatus," Nuckols, M.L., Clarke, J.R., and Marr, W.J., Intl J. of Life Support and Biosphere Science, Vol 6 (1999), pp 239-249.
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TEST PLAN NUMBER: 00-21

**UNMANNED TESTING OF A MODIFIED US DIVERS OXYMIX SEMI-CLOSED UBA
WITH VARIABLE EXHAUST VOLUME RATIOS**

December 2000

Submitted:

Reviewed:

Approved:

M. L. NUCKOLS,
US Naval Academy
Task Leader

D. J. SCHMITT
Senior Projects Officer

E. N. CHRISTENSEN
CDR, USN
Commanding Officer

E. T. Long
CDR, MC, USN
T & E Division Head

M. E. KNAFELC
CAPT, MC, USN
Senior Medical Officer

L. J. CREPEAU
LCDR, MSC, USN
Scientific Advisor

UNMANNED TESTING OF A MODIFIED US DIVERS AQUALUNG OXYMIX SEMI-CLOSED UBA WITH VARIABLE EXHAUST VOLUME RATIOS

INTRODUCTION

An analytical model has recently been developed for predicting the circuit oxygen levels in semi-closed underwater breathing apparatus at various mission depths and diver activity levels (Nuckols, Clarke, Marr, 1999). Unmanned testing in June 2000 with a commercially available US Divers Aqualung OxyMix rebreather (NEDU Test Plan Number 00-06 dated May 2000) and in July 2000 with a modified Halcyon rebreather (NEDU Test Plan Number 00-08 dated July 2000) showed good agreement with this analytical model over a wide range of diver depths, orientations and activity levels (Nuckols, Gavin, Finlayson, 2000). Following these tests, an optimization approach was applied to the analytical model to define desired design parameters for the OxyMix rebreather to maximize its excursion depth capability. Optimized exhaust volume ratios (EVR) and supply gas oxygen concentrations have been identified to allow safe operations of the OxyMix design to depths of up to 130 FSW. US Divers has fabricated two modified exhaust bellows of varying volumes for testing to verify the predicted performances of the OxyMix rebreather with modified EVRs and oxygen content in the supply gas. The objective of this testing is to perform unmanned testing with these modified OxyMix rebreathers during simulated missions to 130 FSW to validate their predicted performances.

RISKS/BENEFITS

The risks involved in participating in this study are no greater than those normally associated with operating compressed oxygen UBAs and hyperbaric chamber systems.

METHODS

GENERAL

During June 2000 the U.S. Divers OxyMix 3C, shown in Figure 1, was tested in the Experimental Dive Facility (EDF) at NEDU as outlined by Test Plan 00-06. The OxyMix apparatus functions as a ventilatory-coupled rebreather when in semi-closed mode, but has the capability of being switched to a closed, pure oxygen mode by the diver when in shallow depths. All testing during this test series was unmanned in semi-closed mode.

The OxyMix system is made up of two units, chest and back mounted. The chest unit contains the breathing bellows and carbon dioxide scrubber. The back unit contains three 2-liter cylinders, one containing pure oxygen used during closed circuit mode and the other two containing a nitrox mixture for injection when in semi-closed circuit mode.



Figure 1: U.S. Divers OxyMix 3C. The chest pack contains the breathing bellows and the carbon dioxide scrubber. The backpack encloses the gas supply bottles.

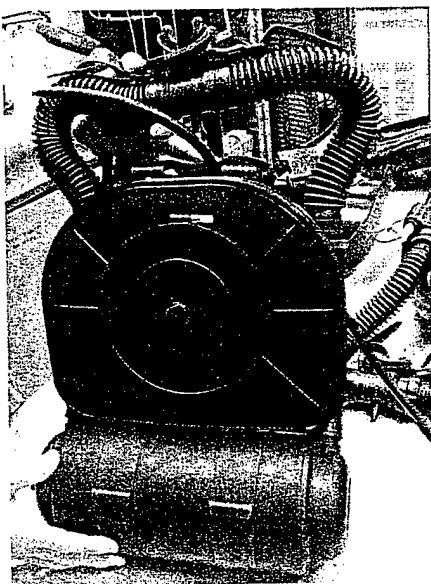


Figure 2: OxyMix 3C with front cover removed showing the main breathing bellows and the carbon dioxide scrubber.

The breathing bellows assembly, shown in Figure 2, contains two bellows, the main breathing bellows which houses a smaller inner bellows.

The small inner bellows, shown in Figure 3, is fixed in position on one end by a fixed inner plate and on the other end by the upper mobile plate attached to the main breathing bellows. Both bellows are concentric and operate together. Their action is proportional to the breathing rate of the diver. Fresh makeup gas is added to the circuit on demand as the bellows collapse during diver inhalation forcing the mobile plate to press on the valve actuator.

Three test depths (20, 60, and 80 FSW) and three RMV levels (22.5, 40, and 62.5 lpm) were investigated during these model validation tests. Corresponding oxygen consumption rates were simulated during each test combination of depth and RMV. PO_2 versus time were monitored in the breathing circuits of two OxyMix rigs at each depth/RMV combination while simulating diver oxygen consumption until stabilized PO_2 levels were observed. A nitrox mixture containing 50% oxygen was used as the makeup gas at all test conditions. Both rigs were tested at each depth/RMV combination twice to confirm the repeatability of test data. Different diver orientations (prone, supine and vertical) were tested to determine whether diver position would have any impact on these circuit oxygen levels.

This previous testing verified that circuit oxygen levels were repeatable and remained constant over the range of activity levels tested. This constant and repeatable circuit behavior is extremely desirable for a mission in which a wide range in diver activity levels could occur. In addition these results indicated that the OxyMix mission capability could be extended significantly by changing the exhaust volume ratio (EVR), the ratio of the small inner bellows volume relative to the main breathing bellows, and supply gas oxygen concentrations.

For the current testing, the Task Leader will provide two (2) U.S. Divers OxyMix rigs, one off-the-shelf and one modified, having two different exhaust bellows of varying EVR's for testing in semi-closed circuit mode only. Modified rigs containing EVRs of 6.25% - 7.5% are predicted to give the OxyMix a depth capability of up to 130 Fsw, while maintaining maximum circuit PO_2 levels, when using a supply gas containing 37% oxygen. All testing will be unmanned



Figure 3: View of inner exhaust bellows.

using one of the Experimental Diving Facility (EDF) chambers, a breathing simulator, and the EDF oxygen consumption simulator. Data to be recorded will be UBA circuit PO_2 versus time at various depths and respiratory minute volumes (RMVs). T&E support personnel requirements include one supervisor, one chamber operator, and one instrument technician. The Task Leader will be present during all testing to analyze test data and validate mathematical models.

EXPERIMENTAL DESIGN AND ANALYSIS

The objective of this current testing is to generate a database of PO_2 versus time for an off-the-shelf and two modified OxyMix rebreathers containing EVRs of 6.25% and 7.5% during simulated missions that can be compared with predictions made by current mathematical models. The potential payoff from this effort will be the ability to optimize the designs of these semi-closed UBAs to extend the depth capability for specific mission requirements. Three test depths (20, 75, and 130 FSW) and two RMV levels (22.5 and 62.5 lpm) will be investigated. PO_2 versus time will be monitored in the breathing circuits of these OxyMix rigs at each depth/RMV combination while simulating diver oxygen consumption until stabilized PO_2 levels are observed. Two different nitrox mixtures containing approximately 30-40% oxygen will be used as the makeup gas for each rig at all test conditions. The exact supply gas oxygen contents will be specified following static volume measurements of each rig in the EDF prior to the unmanned testing. All three rigs will be tested at the same depth/RMV combinations to confirm the repeatability of test data.

EQUIPMENT AND INSTRUMENTATION

EDF Alpha or Bravo chambers, Reimers or Battelle breathing simulators, one off-the-shelf and two modified US Divers OxyMix UBA's, Rosemount 755 oxygen analyzer, Matheson mass-flow controller, Labview PC data acquisition software, 8-12 mesh D-Grade Sofnolime CO_2 absorbent.

Makeup gas will be provided from the OxyMix nitrox bottle filled with approximately 30-40% oxygen (exact oxygen content will be determined following static circuit volume measurements prior to testing); EDF bottle field air for compressing chambers. Temperature set at 70°F (21°C).

PROCEDURES

The Task Leader will provide three OxyMix rigs, one off-the-shelf and two modified, to NEDU for testing in semi-closed circuit mode. Testing will be conducted for each rig at 3 test depths of 20, 75 and 130 feet of seawater (FSW) in a vertical orientation. Testing will be conducted at all depths while simulating respiratory minute ventilation rates (RMVs) of 22.5 and 62.5 liters per minute (lpm). Corresponding oxygen consumption rates will be simulated during each test combination of depth and RMV as shown in Table 1. CO₂ generation will NOT be simulated during these tests; however, the absorption canister will be packed as prescribed by US Divers to simulate normal diving configuration. During all testing the rigs will be submerged in a water bath at a temperature of approximately 70°F.

- a) Prior to commencement of testing for each rig, the following baseline calibrations are to be completed. Results are to be reviewed and approved by the test director.
 - a. Calibrate all pressure transducers in accordance with their pressure ranges, ensuring as a minimum a zero reference point, mid-range and full-scale point.
 - b. Calibrate the Rosemount 755 oxygen analyzer over the anticipated ranges of the UBA performance characteristics.
 - c. Verify that the UBA has been configured according to manufacturer's operational specifications as per OxyMix Users Manual.
 - d. Verify that ark temperature is within specified parameters.
 - e. Ensure completion of EDF chamber operating procedures, test equipment connections and all calibrations are complete.
 - f. Record UBA test specifics in the EDF Diving Supervisors log and install on test stand in the upright position.
 - g. Lower UBA into ark and verify UBA and test support equipment is gas tight (leak check).
 - h. Perform final systems checks, all instrumentation functioning.
- b) Testing will begin by pressurizing the water bath to a simulated depth of 130 FSW at a travel rate of 60 FSW/min. Upon reaching 130 FSW, a simulated respiratory rate of 22.5 lpm will be initiated and PO₂ versus time will be recorded until stable levels are reached. Following stability the RMV will be increased to 62.5 lpm and PO₂ versus time will be recorded until stability is met.
- c) Following testing at 130 FSW, the chamber will be vented to a simulated depth of 75 FSW at a travel rate of 60 FSW/min. PO₂ versus time will be recorded continually during this ascent period. Upon reaching 75 FSW testing will be conducted in the reverse order of that used during previous testing at 130 FSW, ie, PO₂ versus time recorded at the highest RMV initially followed by testing at the lower RMV.
- d) After completing tests at 75 FSW, the chamber will again be vented to a simulated depth of 20 FSW at a travel rate of 60 FSW/min, continually recording circuit PO₂

versus time during the ascent. Upon reaching 20 FSW testing will be continued with the order of RMV testing set at 62.5 lpm followed by 22.5 lpm.

- e) Following testing at all depth/RMV conditions with the initial make up gas supply, testing will be repeated as prescribed above with the second make up gas supply.
- f) Following testing of the first OxyMix rig at all depth/RMV conditions, testing will be repeated with the other two rigs using the same procedure as described above while monitoring PO_2 versus time until stability in circuit PO_2 is observed.

Table 1. RMV/ O_2 consumption schematic.

<u>RMV RATE</u>	<u>O_2 CONSUMPTION VALUE</u>
22.5	0.9 LPM
62.5	2.5 LPM

TERMINATION CRITERIA

During testing at each depth and RMV, PO_2 versus time will be recorded until stable levels are reached, or until terminated by the test Task Leader. Stability will be assumed when PO_2 changes less than 0.01 Ata in 5 minutes.

REFERENCES

1. NEDU TM 01-94, *U. S. Navy Unmanned Test Methods and Performance Goals for Underwater Breathing Apparatus*
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CHAPTER VI

FIGURE 5

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